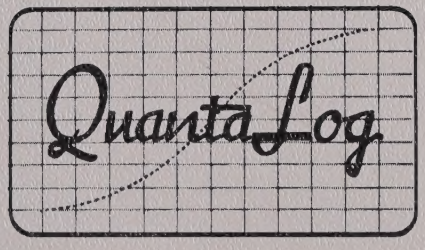
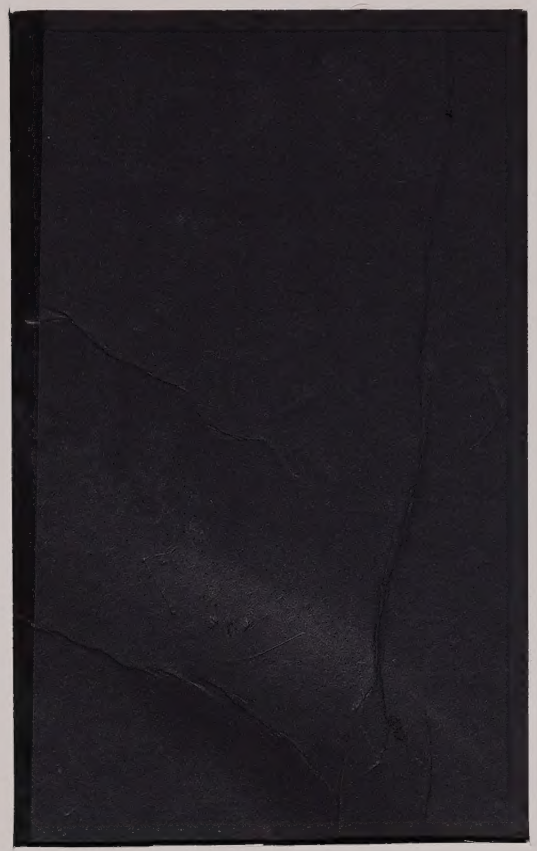
OWNER'S MANUAL
FOR THE
OPERATION, MAINTENANCE, AND
TROUBLE-SHOOTING
OF THE
MACBETH QUANTALOG
DENSITOMETER
MODEL RD-100

MACBETH



INSTRUMENTS



Should it become necessary to return your instrument for repair, please complete the following:

Instrument Model #_____ Serial #_____

Your Name_____

Company_____

FOLD ALONG THIS LINE

Street_____

City_____ State_____ Zip_____

Describe briefly any malfunction or symptoms____

This information will allow us to expedite the repair of your instrument and assure you of minimum repair charges.

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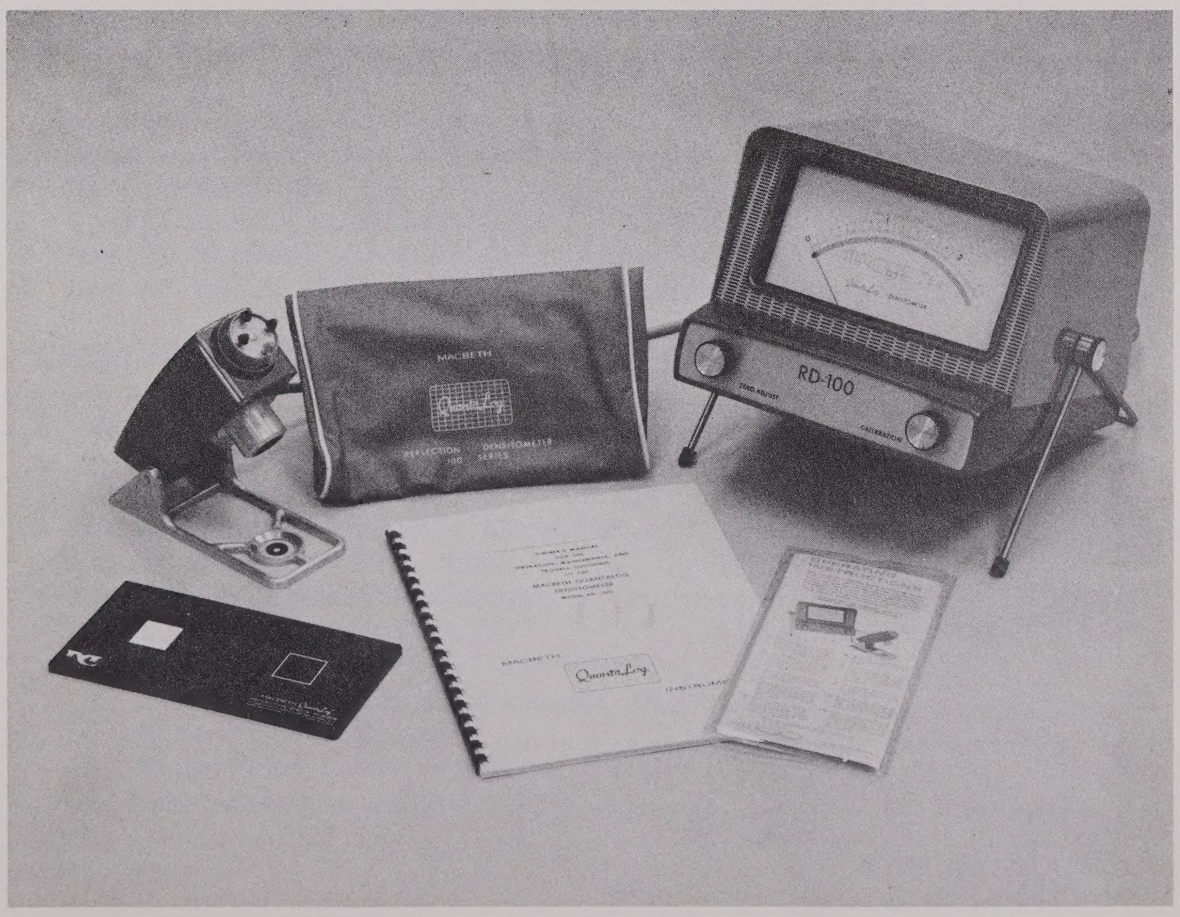

Price $5.00

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I GENERAL INFORMATION

A - INTRODUCTION

This manual, which includes operating instructions, construction details, maintenance data and trouble shooting information, has been prepared to enable you to enjoy optimum performance from your Macbeth QuantaLog Reflection Densitometer, Model RD-100. The RD-100 has been developed to fill the need for an easy-to-operate, reliable, precision color and black-and-white reflection densitometer. The information set forth in this manual will enable you, over the years, to get maximum efficiency and reliability from this instrument. For this reason, the little time you invest now in acquainting yourself with the theory and practice behind this fine and unique densitometer will be of great value to you throughout its long life.

B - APPLICATION

The RD-100 has application in areas where measurements of diffuse color and black-and-white reflection densities are important, particularly where those measurements may be critical for establishing and/or insuring consistent color quality.

For close control of black and white or colored ink film thickness in the printing process, the RD-100 has no equal.

Color density measurements on photographic paper test strips are easily accomplished with the RD-100.

If information beyond the scope of this manual is required, please contact the Macbeth Instrument Corporation, Technical Sales and Service Department, Newburgh, New York 12550.

C - GENERAL PRINCIPLES OF OPERATION

This new, single purpose, instrument is designed to make it possible, even for the unfamiliar user, to make rapid, reliable, accurate and reproducible reflection density readings in black and white and/or color. This has been accomplished by the development of a new optical system that yields A.S.A. Diffuse Reflection Density, combined with a mechanical design that allows the operator to select the area to be measured; to position the measuring probe with unfailing accuracy over the area selected and to take a measurement of this area in a matter of seconds.

The readings taken with your RD-100 Reflection Densitometer indicate American Standards Association Diffuse Reflection Density. Because the electronic design is basically the same as in other Macbeth QuantaLog instruments, the meter scale is linear with optical diffuse reflection density and density graduations are equally spaced.

D - OPERATING REQUIREMENTS

1 - Power Consumption

The total power consumed by the RD-100 is approximately 30 watts. This includes the power to operate the electronic circuits, optical light source and anti-fatigue lamp.

2 - Operating Voltage

The power transformer of the RD-100 has been designed for either 115 or 230 volt operation at power line frequencies of 50 or 60 cycles per second. The data tag on the back of each instrument indicates the specific operating voltage for which it has been adjusted (Refer to Section VI, Exhibit D, of this manual for instruction, if this operating voltage is to be changed.)

3 - Voltage Regulation

The electronic power supply of the RD-100 is self-regulated and hence is not affected by normal line voltage variations. However, line voltage variations will affect the stability of the energy radiated by the optical system light source. Therefore, a voltage regulator must be used to prevent these fluctuations from causing reading errors. A simple 30 volt ampere voltage regulator is adequate for this purpose.

4 - Ambient Illumination

The RD-100 is designed for operation under all normal conditions of ambient illumination. Its performance is equally unaffected by operation in either a dark-room, (meter scale is not illuminated, therefore, some form of illumination is required when reading the scale under these conditions), or by a sun-lit window.

E - PERFORMANCE SPECIFICATIONS

1 - Mechanical

Single purpose reflection densitometer requiring no auxiliary plug-in attachments.

New measuring technique - a unique mechanical design makes possible a new measuring technique which prevents operator variables from influencing the precision designed into the instrument. The specific features of this design are:

(a) The Probe weighs only 31 ounces and is permanently wired to the Photometer with a small diameter, highly flexible cable.
(b) The Probe snout automatically pivots clear of the operator's field of view while the Probe is being positioned.
(c) A 3/16-inch diameter "bull's-eye" in the Probe stand facilitates rapid and accurate positioning of the Probe over the sample area to be measured.
(d) A slight downward fingertip pressure moves the measuring element of the Probe from its normal standby position to its reading position in the stand over the sample.
(e) The Probe snout comes to the same pre-determined fixed mechanical stop in the stand for every reading, thereby eliminating the possibility of different readings by different operators.
(f) An automatic switch in the Probe mechanism prevents any meter readings until the Probe snout is correctly seated in the stand.

2 - Optical System Light Source and Collection Optics

Optical system geometry meets A.S.A. specifications for measuring diffuse reflection density - the incident radiation is normal to the sample surface and the collection system accepts the radiation which is reflected through a combination heat absorbing and dichroic filter (which is permanently installed in the optical system) at all azimuth angles between 0 and 360° and at the elevation angles of 45° ±5°.

3 - Filters

A Color Filter Turret assembly on the front of the Probe permits an operator to "dial-in" the required color filter. The standard instrument is equipped with Wratten red, green, blue and visual filters (#25; #58; #47 and #106).

The Filter Turret assembly can be snapped out and alternate Filter Turrets are available as an accessory, which the user can equip with filters of his own choice.

To change filters, simply remove the turret as described on Page 7 and take out the retaining ring which holds the present filters in place. The new Wratten filter material should be cut into circles 9/16" in diameter and can be placed and held in position with the retaining ring.

A set of simple mechanical Filter Trimming Controls are provided in the Filter Turret which provides the user with the flexibility to pre-set zero for each filter position before each series of measurements.

Separate Filter Turret Assemblies can be obtained from your authorized Macbeth dealer or from the Macbeth Instrument Corporation.

4 - Electronic

The electronic circuitry employs a photomultiplier tube in a dynode feed-back loop, which results in an instrument whose meter readings are a linear function of optical density.

An electronic calibration circuit makes it possible to calibrate any number of instrument to a common standard, regardless of the inherent variations which exist within groups of any photodetectors.

The self-regulated D.C. circuit is not affected by large variation in frequency, wave form, or voltage. Therefore, only a small, commercially available 30 V.A. constant voltage regulator is required to maintain stable operation of the optical system light source.

The linear 0 to 2.50 density scale is divided into 125 graduations each equal to 0.02 density units. Instrument readings are precise within a tolerance of ±0.02 density units and reliable operating readings can be made with a repeatability of ±0.01 density units.

F - ACCESSORIES SUPPLIED

The purchase price of your RD-100 includes the following accessories (shown in photo on title page) which you will find enclosed in the shipping carton:

1. One Instrument dust cover
2. One operator's manual and warranty card
3. A transparent envelope with simple operating instructions
4. A 2 step (black & white) Reflection Check Plaque for Zero Adjust and Calibration Control setting

II - OPERATING INSTRUCTIONS

A - REFLECTION CHECK PLAQUE

The Reflection Check Plaque supplied with the instrument is used for the Zero Adjust and Calibration Control settings as outlined below in B.

This Plaque consists of a white and near black ceramic area, baked on a metal plate.

The A.S.A. diffuse visual reflection density value for each area is indicated on the back of this plaque.

The ceramic areas have a high stability and are reasonably resistant to abrasion in normal use. However, since this is a reflection "STANDARD" reasonable care should be exercised in its

use, and the surface, specifically the near black area, should be kept clean and free from dust, scratches, and finger prints.

Cleaning can be accomplished with a mild detergent in warm water.

B - FUNCTION OF OPERATING CONTROLS

The operating controls for the RD-100 are located on the front of the main electronics housing (See Figure 1) and on the Filter Turret on the Probe (See Figure 2) and are therefore always in full view and easy reach of the operator. The function of these controls is described below and they should be operated in the sequence in which they are presented.

1. ON-OFF AND ZERO ADJUST
   This control performs a dual purpose. It is a combined power "On-Off" switch and Zero Adjust Control

   (a). Rotating this control clockwise supplies AC power to the instrument after it has been plugged into a suitable regulator (for details, see Figure 1 of this manual).
   (b). This control must be rotated further clockwise to set the meter for a zero scale reading. This control has equal response on all four filter positions.
   The individual Filter Trim Controls (zero-adjust drivers) located on the Filter Turret (Figure 2) are used as individual zero adjusts for each filter position.

   NOTE: The instrument will read below meter zero until the measuring Probe is brought in direct contact with the stage disc.

   (c). To set zero on the meter scale for all filter positions, proceed as follows:
   Position the aperture of the measuring Probe approximately in the middle of the white area on the Reflection Check Plaque as shown in Figure 2. Rotate the Zero Adjust Control on the main electronics housing fully clockwise. Rotate the Filter Turret to the Visual Position (gold Filter Trim Knob on the bottom). Rotate the Visual Filter Trim Control fully clockwise and note this reading. Rotate the Visual Filter Trim Control counter-clockwise until the meter reads 0.10 density units below the first reading. Rotate the Zero Adjust Control on the main electronics housing counter-clockwise until the meter indicates a reading that coincides with the value given for the white portion of the Reflection Check Plaque*. Rotate the Filter Turret to the red filter position (red Filter Trim

Control in the down position) and adjust the red Filter Trim Control until the meter indicates the value of the white portion of the Reflection Check Plaque. Check through the green and the blue filter positions in the same manner and adjust the appropriate Filter Trim Controls to the value of the white portion of the Reflection Check Plaque. If the value of the white portion of the tile (as indicated on the reverse side of the plaque) cannot be obtained, the light source intensity will have to be reset. Refer to Chapter IV, A2, "Light Source Rheostat Adjustment," for this procedure.

Note: The calibration of the Reflection Check Plaque is given for the visual filter position only, and for this reason, calibration should only be checked with this filter position.

2 - Calibration Control

The Calibration Control is used to adjust the meter pointer to read a specific upscale reflection density reading for which the instrument was calibrated at the factory. To set this control:

(a) Turn the Filter Turret to the visual position (gold Filter Trim Control in down position) and let the measuring Probe come to rest in the up position. Place the aperture of the measuring Probe approximately in the middle of the dark portion of the Reflection Check Plaque (see Figure 3) and with the measuring Probe down, adjust the Calibration Control on the main electronics housing until the meter reads the indicated reflection density value for this step.
(b) Recheck the white portion of the Reflection Check Plaque again with the visual filter position in place and adjust the Zero Control if necessary.
(c) Recheck your calibration setting with the visual filter in position and readjust the Calibration Control if necessary.
(d) Check your red, green and blue down scale setting on the white portion of your Reflection Check Plaque and adjust the appropriate Filter Trim Controls for these filters.

C - WARM-UP AND PERIODIC CALIBRATION CHECK

The RD-100 has been designed for rapid warm-up, but at least 30 minutes should be allowed to permit all components to arrive at thermal equilibrium. This is a manually operated and manually calibrated instrument, therefore, it is recommended that the "Zero" Adjust and Calibration Control settings be checked before each series of readings.

D - METER READINGS

The meter has a linear, 0 to 2.50 Density scale (See Figure 1). The scale graduations are equally spaced in 0.02 Density increments and the knife edge pointer permits the operator to read reliably to 0.01 Density units over the entire range. A mirrored meter scale prevents reading parallax.

E - CHANGING FILTER ASSEMBLY

In order to change a complete Filter Turret Assembly, the operator should rotate the Filter Turret Knob so it is positioned between the detent stations. He can then pull the complete assembly out of the measuring Probe (See Figure 4) by holding the measuring Probe steady with one hand and exerting a straight pull on the Filter Selector Knob. Because it is a snap-in fit, the entire Filter Turret Assembly will come out easily. A new Filter Turret Assembly may be snapped in place.

The RD-100 Reflection Densitometer is normally equipped with one Filter Turret Assembly, containing Wratten Red, Green, Blue and Visual Filters. All filter positions are adjusted at the factory with Neutral Density trim filters.

Other Filter Turret Assemblies may be obtained from your authorized Macbeth dealer or from the Macbeth Instrument Corporation, Newburgh, New York 12550.

F - USE OF MACBETH 10-STEP CALIBRATED CHECK PLAQUE

So far reference has been made only to calibration through the visual filter on the white and black area of the Reflection Check Plaque supplied with the instrument.

The original factory calibration of the RD-100 is set up on a 10-Step Macbeth Calibrated Reflection Density Check Plaque. This 10-step check plaque is available as an accessory item for those who wish to check the absolute density readings over the entire reflection density range of the instrument. If any major component of the instrument is changed (such as a P.M. tube) recalibration of the instrument is usually required using the 10-Step Check Plaque.

G - USE OF KODAK REFLECTION CHECK PLAQUE

The Kodak Reflection Check Plaque is used to check long term instrument color drift. It consists of two photometric areas for checking zero adjust and calibration point, and three (Red, Green & Blue) color patches that make it possible to keep a close check on the day-to-day color response of the instrument. Complete instructions for its use are supplied by the Eastman Kodak Company

with this item.

To obtain the Macbeth 10-Step Reflection Density Standard contact your authorized Macbeth dealer or The Macbeth Instrument Corporation at Newburgh, New York 12550.

III INSTRUMENT SYSTEMS, PRINCIPLES AND CONSTRUCTION DETAILS

A - THEORY

The theory of operation of the RD-100 electronic circuitry is based upon a photomultiplier tube dynode voltage feedback circuit which automatically adjusts dynode voltage applied to a photomultiplier tube so as to maintain a constant P.M. tube anode current. Light from a light source (See Figures 5 and 6) is projected onto the sample. Diffuse light reflecting from this sample is collected and reflected by the annular ring through the measuring filter and imaged on the photomultiplier tube cathode. The dynode voltage change required to maintain a pre-set anode current for any particular amount of light falling on its photo-sensitive cathode is used as an approximate measure of the optical reflection density of the sample. Figure 5 is a diagram of this overall system. If, for example, the light flux falling upon the photo-sensitive surface of the photomultiplier tube decreases, as when a darker sample is introduced, the input signal to the voltage amplifier decreases. This signal is amplified and fed into the input of the power amplifier which controls the output voltage of the high voltage power supply. For the case cited, the output dynode voltage of the high voltage power supply increases in order to maintain a constant anode current within the photomultiplier tube. The voltmeter which constantly measures this voltage will now indicate a higher voltage. Since the meter is calibrated in density units, this increase in voltage indicates an increase in reflection density. The Dynode Voltage of a typical RD-100 will vary between approximately 300 and 650 volts for samples whose optical reflection densities fall between 0 and 2.50. This is not a completely linear relationship however, and therefore a compensating circuit is used to calibrate the voltmeter readings to a given reflection density standard.

B - DETAILS OF OPTICAL SYSTEM

1 - Imaging and Collection Optics

All details of the RD-100 optical system are schematically depicted in Figure 6. Light in the optical system light source is collumated and directed at a 90° angle incident to the plane of the sample, by the imaging lens. Light reflected from the sample at 45° ±5°, through a 360° cone, is collected and reflected

by the annular ring through the heat absorber and dichroic filter and the measuring color filter, onto the photo-cathode of the photo-multiplier tube.

The measuring filter holder is mechanically adjustable backwards and forwards in the light beam. This acts as a variable area aperture and attenuates the light thereby effectively providing a means for trimming each color filter to have the same density or meter zero point.

The filters installed in the filter assembly are the Red, Green, Blue and Visual #25, #58, #47 and #106 Wratten filters.

The Filter Turret Assembly, complete with filter holders and Filter Trim Knobs is readily interchangeable with separate Filter Assemblies in which special filters can be installed. The Visual filter is installed to obtain the spectral conditions detailed by the American Standards Association for the measurement of diffuse Visual reflection density. This optical system complies with the geometric specifications set forth by the American Standards Association in PH.2.17-1958 for the measurement of diffuse reflection density.

C - DETAILS OF ELECTRONIC CIRCUIT

The details of the electronic circuit are covered below under separate headings which correspond to the blocks shown in the overall system block diagram (Figure 5).

1 - Photomultiplier Tube

A simple photo tube consists of two elements - a photo electric emitter, or cathode, and a collecting anode enclosed within an evacuated glass envelope. If sufficient potential is applied between these elements, current will flow through the tube when its cathode is bombarded by incident photons. This current is extremely small when the cathode is exposed to low light levels, and must be amplified by electronic circuits external to the tube itself. In a photomultiplier tube, however, amplification of the photoelectric current is accomplished by the addition of a dynode structure between the cathode and anode of the simple phototube. This structure usually consists of nine or more dynode stages, each operating at a slightly higher potential than the preceding element (See Figure 7). These dynodes emit copious amounts of electrons by secondary emission when excited by incident electrons. The dynodes are shaped so that the electrons leaving one dynode are guided to the next by an electrostatic focusing action. It is possible to realize a 400,000 times amplification of the initial photocathode current within a 931-A photomultiplier tube when it is operated at approximately 100 volts per dynode stage.

A photomultiplier tube is usually employed as a current-generating device in most circuit applications, that is, a constant dynode voltage is applied to the tube, and its current output is used as a measure of the light flux incident upon its photocathode surface (I in Figure 5). This relationship between light flux falling on the photocathode (I) and the tube current is essentially linear. If, however, the tube current is related back to the flux that is incident upon a sample (I Figure 5) then the relationship between I and the tube current is logarithmic. In other words, if the output current of a photomultiplier tube is used in a photometer to directly measure the reflection density of a sample, then the density scale of the photometer must be logarithmic (sample density B is equal to log I).

This is undesirable since scale markings will spread out at low density readings, and will be extremely crowded at high density readings.

This situation can be overcome, however, by employing a photomultiplier tube as a constant current device and measuring its dynode voltage instead. In this circuit application, the dynode voltage is constantly adjusted electronically to maintain a constant current through the tube, regardless of the amount of light flux incident upon its phototube. The relationship between dynode voltage and optical density now becomes nearly linear since the dynode voltage is approximately equal to the negative logarithm of the light flux reflection from the sample (I).

Hence, the RD-100 employs a highly sensitive photomultiplier detector in a unique dynode feedback circuit whose output is very nearly linear with reflection density. The other advantages of this circuit are described below:

2 - Dynode Feedback Circuit

There are several advantages to the use of a dynode feedback circuit for operating a photomultiplier tube in addition to the fact that this circuit yields a nearly linear relationship between density and dynode voltage.

First, this mode of operation is tantamount to operating the photomultiplier in the conventional way, but under the ideal conditions of constant dynode voltage and with a constant level of incident flux. The result is maximum stability within the tube itself.

Second, this circuit eliminates the need for the precision-stabilized high voltage source required in conventional circuits.

Third, this feedback feature permits operation of the photomultiplier at greatly reduced dynode voltages during the periods between density readings, thereby minimizing the deleterious effects of photomultiplier tube fatigue (See Section III-C-8).

The photomultiplier tube in this instrument is used in a feedback loop which automatically adjusts its dynode voltage to keep the anode current constant (Figures 5 and 7). A signal is developed across R1 which is then amplified in the d.c. amplifier stage using a 12AU7 (V1). This amplified signal is fed to the input of a 6GW6-A power amplifier tube (V2). The plate circuit of this stage consists of the high voltage power supply, which uses a 1B3 rectifier (V3), and an impedance consisting of the dynode resistor string (R12 through R20).

If less light flux is received (increase in sample reflection density) by the photomultiplier tube, then the signal appearing across R1 decreases (becomes less negative). This amplified signal appears at the input of V2 as a decrease in bias (grid becomes more positive) and hence the plate current of V2 increases. This increases the negative voltage applied to the cathode and dynode resistor string. Therefore, the gain of the photomultiplier tube is increased and the anode current is restored to its original value.

3 - Compensating Circuit

If the operating characteristics of the dynode feedback circuit are plotted as Dynode Voltage vs. Diffuse Reflection Density, it will be seen that a perfectly linear relationship does not exist (Exhibit A). Note that the curve shown for the uncompensated dynode voltage is essentially logarithmic. Since it is desirable to obtain meter readings that are equally spaced for equal increments of reflection density, a compensating circuit is used to obtain the instrument characteristics that are represented by the dashed-line labeled "Compensated Dynode Voltage Characteristic."

Note in Figure 7 that the microammeter, in series with a 27K (R26) resistor and a 1.6 Meg Ohm (R23) resistor is connected across the dynode resistor string (Point X to Ground). This is in effect a voltmeter which would yield a curve similiar to the one shown in (Exhibit A) for uncompensated dynode voltage characteristics.

The compensating circuitry consists of two independent, parallel circuits (bounded by a dashed - line) which shunt that portion of the dynode voltage which appears across the meter. Each contains two potentiometers known respectively as a "CUT-IN" potentiometer (R27 and R31) and an "EFFECT" potentiometer (R28 and R32); and a diode (CR1 and CR2). These potentiometers are set (See "Calibration Procedure" outlined in Section IV) at the points indicated on the curve in (Exhibit A) to yield a straight line for meter readings vs. diffuse reflection density.

The two cut-in potentiometers (R27 and R31) are connected

across a zener diode (CR4) which provides a constant reference voltage of - 11 volts for the compensating circuitry. The setting of each cut-in potentiometer determines the voltage at which a particular diode will begin to conduct, and the corresponding effect potentiometer determines how much current it will conduct. For example, the setting of R27 determines when CR1 will begin to conduct, and the setting of the effect potentiometer R28 determines its conduction current. The instrument meter measures the voltage appearing between Point X and Ground.

4 - Calibration Control Circuit

The Calibration control circuit which shunts the meter consists of a fixed resistor (R25) and the Calibration control potentiometer (R24). This control is used as a fine adjustment for the voltage appearing across the meter while reading the reflection density for the dark portion of the reflection check plaque supplied with the instrument (See Section II).

5 - Meter Zero Bucking Voltage Adjust Circuit

The meter zero bucking voltage adjust circuit consists of a fixed resistor (R21) and a potentiometer (R22) connected between a regulated voltage of approximately 85 volts and the instrument meter. This circuit is used as a source of bucking voltage to set up the meter zero during initial factory calibration or when a photomultiplier tube is changed (See Section IV).

6 - Zero Adjust Circuit

The Zero Adjust Circuit consists of a fixed resistor (R5) and a potentiometer (R4) connected to a regulated voltage of approximately 140 volts. The setting of the Zero Adjust potentiometer sets the operating bias of the first amplifier tube (V1) which provides for an operator adjustment to compensate for gradual aging of the light source or slight changes in overall circuit sensitivity.

7 - Regulated Power Supply

The regulated power supply consists of a full-wave 6X4 rectifier tube (V4), and RC filter (R11 and C2), and two voltage regulator tubes (V5 and V6). This power supply furnishes all of the d.c. requirements for the voltage and power amplifier stages, as well as for the compensating and bucking circuits. The high degree of circuit stability realized in this instrument is determined by the excellent regulation of power supply. As stated earlier, a 30 V.A.

external line voltage regulator is required only to stabilize the intensity of the optical system light source.

8 - Anti-Fatigue Light

All photodetectors, including photomultipliers, may exhibit a change in their anode currents, with no change in the amount of incident light flux. This effect is commonly known as fatigue. Several factors affect the degree and rapidity of these changes, but fatigue in a photomultiplier appears to be principally determined by the average tube current and the material used to coat the dynode surfaces. Fatigue can either be an increase or decrease in sensitivity, although the latter is by far the most common situation.

It appears that most photomultiplier fatigue is the result of a change in the secondary-emission characteristics of the dynode stages. This is probably caused by migration of cesium from the dynode to the other surfaces within the tube, thereby effectively reducing the tube's amplifying capabilities. The effects of this type of fatigue can be mitigated under practical operating conditions, by applying the required dynode potentials, only while readings are actually being made and by operating the tube at the lowest possible dynode voltages.

The dynode feedback circuitry of this instrument, together with an antifatigue light (L2), permits operation of the photomultiplier tube on a "standby" basis between readings. The anti-fatigue lamp (See Figures 6 and 7) is positioned next to the photomultiplier tube and is energized through S3, a microswitch (See Figure 7) whenever the Probe is in the "up" position. The shield on this lamp (L2) is rotated until the dynode feedback circuit automatically adjusts the dynode voltage at approximately 270 volts (30 volts less than the dynode voltage for Zero density) in the "standby" position.

The anti-fatigue light and dynode feedback circuit, together with the use of a very efficient optical system, virtually eliminates the effects of photomultiplier fatigue in the RD-100.

D - DETAILS OF ELECTRICAL CIRCUITS

The circuit details of the electrical system are covered in Figure 7. All input a.c. power is fed through a three-prong linecord plug. S1 is a safety interlock switch which is in the "open" position whenever the instrument cover is removed (See Figure 8). The instrument fuse F1 is located on the rear of the Chassis (See Figure 8). S2 is the main "On-Off" switch located on the front, left hand side of the electronics housing (See Figure 1) and is ganged with the Zero Adjust potentiometer.

1 - 115 or 230 Volt Operation

Note that the power transformer (T1) primary is shown wired for 115 volt operation. If the instrument is to be operated from 230 volts, this wiring must be changed in accordance with the information tabulated in "Transformer Specifications - Exhibit D", and referring to Figure 7.

2 - Light Source Wiring

The optical system light source (L1) is operated through the fixed resistor R34, from the 6.3 volt winding of T2. The intensity of the light source L1 is adjusted manually, by removing the cover from the main photometer housing. Rotating the rheostat R33, which is located on top of the meter bracket, adjusts the voltage supplied to L1. Rotating clockwise diminishes the voltage supplied (meter will read to the right), counter clockwise adjustment increases the voltage (meter will read further left).

3 - Anti-Fatigue Light Source

The anti-fatigue light source (L2) also is operated from the 6.3 volt winding of the transformer T2. Power from the winding is supplied to the anti-fatigue lamp through the Probe microswitch S3. S3 is normally closed with the Probe in the "up" position so that the anti-fatigue light source is in operation at all times except when making reflection density measurements.

E - MECHANICAL DETAILS

The RD-100 Photometer consits of a die-cast housing, which contains most of the electronic components and the meter readout device.

The optical system light source, collection optics, photo-detector, related electronics components and Filter Turret are housed in an aluminum die-casting which is connected to the main electronics housing with a flexible cable. The photometer cover, including the perforated front and back plates, is of sheet metal construction. This cover is held in place by two knurled cover screws which also act as a pivot for the die-cast main electronics housing on the stainless steel stand. The entire instrument is finished in a baked two-tone, satin gloss, metallic blue-gray epoxy paint.

1 - Probe Mechanism

The details of the RD-100 Probe mechanism are shown in

Figure 6. The Probe consists of a fixed base which is placed in contact with the surface of the sample whose reflection density is being measured, and a photomultiplier housing which pivots vertically about a shaft that passes through two bearings in the fixed base. The normal stand-by position in the Probe between readings, is in its "up" position, where it is held by a return spring. The Probe is moved to its reading position by a finger-tip force of approximately eight (8) ounces, until the Probe snout comes to a positive stop, by seating itself within the Probe stand. This seat is tapered to prevent the possibility of reading variations caused by lateral movement between the Probe housing and the Probe stand. The Probe mechanism is automatically spring-returned to its stand-by position whenever the finger-tip force is relieved.

2 - Microswitch Cam

A flat is milled on the surface of the Probe shaft which acts as a cam for operation of the anti-fatigue microswitch. The microswitch plunger is in contact with the Probe shaft at all times, and completes the circuit to the Probe anti-fatigue light whenever the Probe is returned to its stand-by position.

IV - MAINTENANCE INSTRUCTIONS

A - OPTICAL SYSTEM

The optical system of this instrument requires infrequent but regular maintenance and the occasions for component replacement will be rare. Instructions are given below should component replacement become necessary, together with the attendant information required for effecting replacements.

1 - Light Source Replacement

A burned-out light source is easily replaced with a new pre-focused light source assembly as shown in Figure 9. The following procedure should be observed whenever replacement of a light source becomes necessary:

(a) Turn the instrument off.
(b) Remove the photomultiplier housing (See Figure 6).
(c) Unfasten the two wires from the light source from the connections in probe.
(d) Remove the two screws which fasten the Probe snout to the Probe mounting (See Figure 6).

(e) Separate the Probe snout from the Probe mounting.
(f) Remove the three light source assembly retaining screws (See Figure 10).
(g) Remove the light source assembly which contains the burned-out light source.
(h) Install the replacement light source assembly by proceeding backward through Steps a-g given above. No additional light source positioning is required since each light source assembly is factory pre-focused.

2 - Light Source Rheostat Adjustment

The light source rheostat (R33) must be reset whenever a light source or photomultiplier tube is replaced. This adjustment is made by removing the cover of the photometer unit and manually rotating the knurled rheostat shaft (See Figure 8), located on top of the meter bracket and labeled L1. The following procedure should be observed for making this adjustment.

(a) Plug a voltmeter (20,000 ohm/volt) into the dynode jacks which are located on the rear of the instrument chassis (Figure 8).
(b) Set the Zero Adjust Control (R4) to its approximate mid-position.
(c) Depress the Probe and set the light source rheostat manually until the voltmeter reads 290 volts (±10 volts) d.c.

Note: It is also possible to reset the light source rheostat whenever a light source assembly is replaced without the use of a voltmeter, as follows:

(1) Set the Zero Adjust Control (R4) to its approximate mid-position
(2) Set Filter Selector Knob to visual position and adjust Filter Trim Control until instrument reads .10 density less than reading in full clockwise position.
(3) Depress the Probe on the white portion of the tile and set the light source rheostat manually until the RD-100 meter pointer indicates the density for the white portion of the plaque.

3 - Periodic Inspection and Cleaning

It is advisable to check the optical system on a periodic

basis. The following monthly procedure is suggested:

(a) Inspect the bottom of the Probe base and the stage disc for damage or accumulation of dirt.
(b) Check Light source, stage disc aperture and annular ring for possible accumulation of dirt, such as dust, offset spray, photographic emulsion, or ink.
(c) Check optical focus as follows:

    (1) Depress Probe and invert the entire unit.
    (2) Place a piece of translucent white paper over the aperture in the stage disc.
    (3) The image of the filament of the optical system light source should be focused in the plane of the paper, and positioned approximately in the center of the stage disc aperture.

(d) Check for possible light leaks at the aperture by measuring the black area of your Reflection Check Plaque, with and without light from a flashlight falling on the stage disc.
(e) Remove the photomultiplier housing by removing the two photomultiplier housing retaining screws.
(f) Remove the color filter assembly.
(g) Inspect color filters, heat absorber and dichroic filter for cracks or dirt, using a lens tissue to swab away dirt accumulations. Refer to the Replaceable Parts List if your inspection indicates the need for any component replacement.

B - ELECTRONICS

All photometer electronic components, but one, are accessible for replacement by simply removing the instrument cover (Figure 8). It is not necessary to remove the chassis unless R11 must be replaced. This is a 10 watt wirewound resistor however, and its failure is highly improbable. All Probe electronic components are replaceable by removing the two Probe housing screws and removing the cover.

(1) A tube layout drawing is fastened to the inside of the instrument cover (See Figure 8) as an aid in identifying each of the vacuum tubes. Note that this drawing also gives the identity and location of all potentiometers and transformers.

(2) Electronic Components Board:
The components of the electronics system are mounted on a board which is a separate sub-assembly. This board can be tilted back by first loosening the retaining screw located toward the front end of the chassis. Each of the components is identified in Figure 11.

C - CALIBRATION

Calibration of the RD-100 is required whenever a photomultiplier tube is replaced. It is also advisable to check the calibration of your instrument, using the Macbeth Reflection Calibration Check Plaque whenever any other critical electrical components are replaced, such as rectifier tubes, transformers, capacitors or diodes.

The only other auxiliary equipment required to calibrate your instrument is a D.C. voltmeter which has a sensitivity of 20,000 Ohms per Volt, such as a Simpson Model 262, Triplet Model 630-PL, Weston Model 980, or other comparable multimeter. The step-by-step procedure for calibration is as follows:

(a) Plug the RD-100 into a voltage regulator which has been plugged into the power line. (A 30 V.A. voltage regulator must be selected for either 115 volt or 230 volt, 50 or 60 Cycle Operation.)
(b) Plug the DC voltmeter into the dynode voltage jacks which are located on the rear of the chassis. (See Figure 8.)
(c) Set Zero Adjust (R4) Control at mid-range.
(d) Set Filter Selector Knob to visual position. Adjust Visual Filter Trim Control to read 0.10 density less than full clockwise position of this trim control.
(e) Select Step No. 1 on the Reflection Calibration Check Plaque which has an indicated density of approximately 0.07. Depress Probe and set voltage adjust potentiometer (R33) see page 14 D-2, "Lightsource Wiring" for location of this control. Rotate this potentiometer until the multimeter reads -290 ±10 volts.
(f) Rotate the meter zero bucking adjust potentiometer (R22) for a reading on the RD-100 meter scale corresponding to the indicated Step No. 1 density, and set all cut-in and effect potentiometers (R27, R28, R31, R32) fully clockwise. All these controls are located on the top of the meter bracket, (See Figure 8) and are accessible upon removal of the instrument cover. (See drawing in cover for location of all calibration potentiometers).

Note: Removing the cover releases the safety interlock switch (S-1) making the instrument inoperable. It will be necessary to keep this switch actuated with a rod of insulating material, such as wood or plastic, to effect calibration of the instrument.

(g) Select Step No. 3 on the Macbeth Reflection Calibration Standard, which has an indicated density of approximately 0.54, and rotate the Calibration Control (R24) until the Step No. 3 indicated density value is obtained on the meter scale.

(h) Select Step No. 5, which has an indicated density of approximately 0.95, and rotate the first cut-in potentiometer (R27) counterclockwise until the Step No. 5 indicated density value, plus 0.01 density, is obtained on the meter scale.

(i) Select Step No. 7, which has an indicated density of approximately 1.42, and rotate the first effect potentiometer (R28) counterclockwise until the Step No. 7 indicated density value, plus 0.01 density is obtained on the meter scale.

(j) Select Step No. 9, which has an indicated density of approximately 1.99, and rotate the second cut-in potentiometer (R31) counterclockwise until the Step No. 9 indicated density value is obtained on the meter scale.

(k) Select Step No. 10, which has an indicated density of approximately 2.44, and rotate the second effect potentiometer (R32) counterclockwise until the Step No. 10 indicated density value is obtained on the meter scale.

It may be necessary to repeat the entire calibration procedure once or twice until you have attained proficiency through experience. However, the RD-100 is simple to recalibrate and its performance specifications, as outlined in "I" - General Information, of the RD-100 Owner's Manual, can be quickly realized by completing the calibration procedure described above.

D - TROUBLE-SHOOTING

All trouble-shooting can be accomplished without removing the chassis from the main housing. A circuit Trouble-Remedy Chart is given in Exhibit B as a guide for isolating possible malfunctions which may occur. A chart of voltage and resistance measurements is given in Exhibit C to assist in identifying individual defective components. The normal operating voltages are given in Figure 7 as well as in the Electrical and Electronic

Schematic drawing which is fastened to the inside of the instrument cover.

V - REPLACEABLE PARTS LIST

This section describes the major replaceable parts for your RD-100, which are as listed "Electrical-Electronic","Optical", and "Mechanical" components. All parts listed under "Electrical-Electronic" may be purchased directly from the manufacturers indicated, except for those noted with an asterisk. The items bearing an asterisk should be ordered directly from the Macbeth Instrument Corporation, indicating that they are to be used in an RD-100 instrument. All parts listed under "Optical" and "Mechanical" are Macbeth Instrument Corporation stock items and, therefore, should be ordered directly from the Macbeth Instrument Corporation or your authorized Macbeth dealer.

REPLACEABLE PARTS LIST
RD-100

MECHANICAL

Desig.	Part No.	Name of Part and Description	Function	Manufacturer
	21005800	Disc, Stage	Center Optics Over Sample	Macbeth
	50000500	Spring, Probe Return	Probe Return	Macbeth
	04025000	Bearing, Nyliner #4L4-F	Bearing Surface Probe	Thompson
	51000100	Ball, Nylon - .156 Dia.	Filter Wheel Detent	Ace Plastics
	50000400	Spring, Ball Detent	Filter Wheel Detent	Macbeth
	21006200	Screw, Top Cover	Retain Top Cover	Macbeth
	51000200	Washer, Black Nylon	Bearing, Photometer Pivot	Macbeth
	21003200	Knob, Control	Front Controls	Macbeth
	51800200	Washer, Felt	Front Panel Protection	Macbeth

ELECTRICAL-ELECTRONIC

C1	06100800	Capacitor, Paper 0.1 Mfd., 1600 Volts	High Voltage Ripple Filter	Pyramid #CT16-P1
C2	06200600	Capacitor, Electrolytic 20 Mfd., 450 V. #TVA-1709	B+ Ripple Filter	Sprague
CR1, CR2	41100001	Diodes, Dual 6RS1GC1BX1	Impedance Isolation	G.E.
CR4	41100000	Diode, Zener #Z78	10 V. Reference Diode	Schauer
F1	31005001	Fuse, 1/2 Amp. #3AG, 250 V., Slo-Blo	Overload Protection	Littelfuse
L1	30900001	Bulb, Tungsten 3.7 Volt, 0.3 Amp., Osram #3644	Light Source Subassembly	Macbeth
L2	20014000	Bulb, Tungsten 14 V., 0.20 Amp., #1487	Antifatigue Lamp	G.E.
M1	24000500	Meter, 0-2.5 Density 100μA, 6000Ω Impedance	Density Indicator	Weston
R1	36507000	Resistor, Carbon 500M Ohm, 1 Watt, ±10%	Grid Bias	I.R.C.
R2	36104001	Resistor, Fixed, Comp. 100K Ohm, 1/2 Watt, ±10%	Plate Load	Allen-Bradley
R3	36123000	Resistor, Fixed, Comp. 12K Ohm, 1/2 Watt, ±10%	B+ Volt. Divider	Resistance Co.
R4-S2	36104000	Resistor, Comp., Variable W/On-Off Switch 100K Ohm, 2 Watt, Type JSU	Zero Adjust	Allen-Bradley
R5	36823000	Resistor, Fixed, Comp. 82K Ohm, 1/2 Watt, ±10%	Grid Bias-Volt Divider	Allen-Bradley
R6	36394000	Resistor, Fixed, Comp. 390K Ohm, 1/2 Watt, ±10%	Plate Load	Allen-Bradley

REPLACEABLE PARTS LIST
RD-100

ELECTRICAL-ELECTRONIC, Continued

Desig.	Part No.	Name of Part and Description	Function	Manufacturer
R7	36823000	Resistor, Fixed, Comp. 82K Ohm, 1/2 Watt, ±10%	Cath. Bias Volt Divider	Allen-Bradley
R8	36223000	Resistor, Fixed, Comp. 22K Ohm, 1/2 Watt, ±10%	Cathode Bias Divider	Allen-Bradley
R9	36222000	Resistor, Fixed, Comp. 2.2K Ohm, 2 Watt, ±10%	B+ Volt. Divider	Allen-Bradley
R10	36224000	Resistor, Fixed, Comp. 220KΩ, 1/2 Watt, ±10%	Screen Bias	Allen-Bradley
R11	36902000	Resistor, Fixed, Comp. 9K Ohm, 10 Watt, ±10%	B+ Volt. Divider	Koolohm
R12 thru R20	36224000	Resistor, Fixed, Comp. 220KΩ, 1/2 Watt, ±10%	Dynode Volt Divider	Allen-Bradley
R21	36394000	Resistor, Fixed, Comp. 390K Ohm, 1/2 Watt, ±10%	B+ Voltage Divider	Allen-Bradley
R22	36254000	Resistor, Comp., Variable 250K Ohm, 2 Watt, Type JU	Meter Zero Bucking Adjust	Allen-Bradley
R23	36155001	Resistor, Fixed, Comp. 1.5M Ohm, 2 Watt, ±5%	High Voltage Divider	Allen-Bradley
R24	36103001	Resistor, Comp., Variable 10K Ohm, 2 Watt, Type JU	Meter Shunt Calib. Adj.	Allen-Bradley
R25	36472000	Resistor, Fixed, Comp. 4.7K Ohm, 1/2 Watt, ±10%	High Voltage Divider	Allen-Bradley
R26	36273000	Resistor, Fixed, Comp. 27K Ohm, 1/2 Watt, ±5%	High Voltage Divider	Allen-Bradley
R27	36103000	Resistor, Comp., Variable 10K Ohm, 2 Watt, Type JU	Cut Adjust #1	Allen-Bradley
R28	36104002	Resistor, Comp., Variable 100K Ohm 2 Watt, Type JU	Effect Adjust #1	Allen-Bradley
R29	36682000	Resistor, Fixed, Comp. 6.8K Ohm, 1/2 Watt, ±10%	Calib. Voltage Divider	Allen-Bradley
R31	36103000	Resistor, Comp., Variable 10K Ohm, 2 Watt, Type JU	Cut Adjust #2	Allen-Bradley
R32	36254000	Resistor, Comp., Variable 250K Ohm, 2 Watt, Type JU	Effect Adjust #2	Allen-Bradley
R33	36500100	Resistor, Comp., Variable 5 Ohm, 5 Watt, #WN-050	Ref. Light Source Adjustment	Centralab
R34	36180000	Resistor, Fixed, Comp. 18 Ohm, 2 Watt, ±10%	Source Lamp Voltage Limiter	Allen-Bradley
S1	43010100	Switch, Interlock #V3-23	Safety Interlock	Micro Switch
R4-S2	36104000	Resistor, Comp., Variable W/On-Off Switch 100K Ohm, 2 Watt, Type JSU	Zero Adjust	Allen-Bradley
S3	43010200	Switch, Antifatigue #11SM1	Antifatigue Operation	Micro Switch
T1	44000100	Power Transformer - M124C	Power Transformer	Electrical Windings
T2	44000200	Transformer, Filament	Filament Transformer	EPCO

REPLACEABLE PARTS LIST
RD-100

ELECTRICAL-ELECTRONIC, Continued

Desig.	Part No.	Name of Part and Description	Function	Manufacturer
V1	46000000	Tube, Vacuum - 12AU7	Twin Med. Mu Triode	RCA
V2	46000001	Tube, Vacuum - 6GW6A or 6DQ6B	Power Pentode	RCA
V3	46000002	Tube, Vacuum - 1B3GT	High Voltage Rectifier	RCA
V4	46000003	Tube, Vacuum - 6X4	B+ Rectifier	RCA
V5	46000004	Tube, Volt. Reference - OA2	150 V. Regulator	RCA
V6	46000005	Tube, Volt. Reference - 5651	90 V. Regulator	RCA
V7	10000701	Photo Tube, Vacuum - 931-A	Photomultiplier	RCA
	05818300	Line Cord, Gray	Power Cord for 115 V. or 230 V. Operation	Macbeth
	05890401	Probe Cable #22-4MBC-26T	Probe Chassis Interconnect	Chester Cable
	40020000	Socket, Min. Screw Base #5-19XP34	Antifatigue Lamp Socket	Leecraft
	40020001	Fuse Holder, #341001-3AG	Fuse Holder	Littelfuse
	09010001	Jack, Dynode Voltage Black #105-253-1	Test Jack	E.F. Johnson Co.
	09010002	Jack, Dynode Voltage Red #105-252-1	Test Jack	E.F. Johnson Co.

OPTICAL

Red	55002501	Filter, Wratten #25	Red Filter	Eastman Kodak Co.
Green	55005807	Filter, Wratten #58	Green Filter	Eastman Kodak Co.
Blue	55004701	Filter, Wratten #47	Blue Filter	Eastman Kodak Co.
Visual	55010601	Filter, Wratten #106W	Visual Filter	Eastman Kodak Co.
Neutral Density	29000250	Filter Pack, Wratten #96 N.D.	Trimming Filters	Eastman Kodak Co.
	27000060	Filter, Masked, I.R. Rejection	I.R. Rejection Filter	Macbeth
	27001200	Lens, 7mm Dia. x 5mm F.L. Double Convex Coating	Imaging Lens	Edmund Scientific Co.

FIGURE 1

FIGURE 2

FIGURE 3

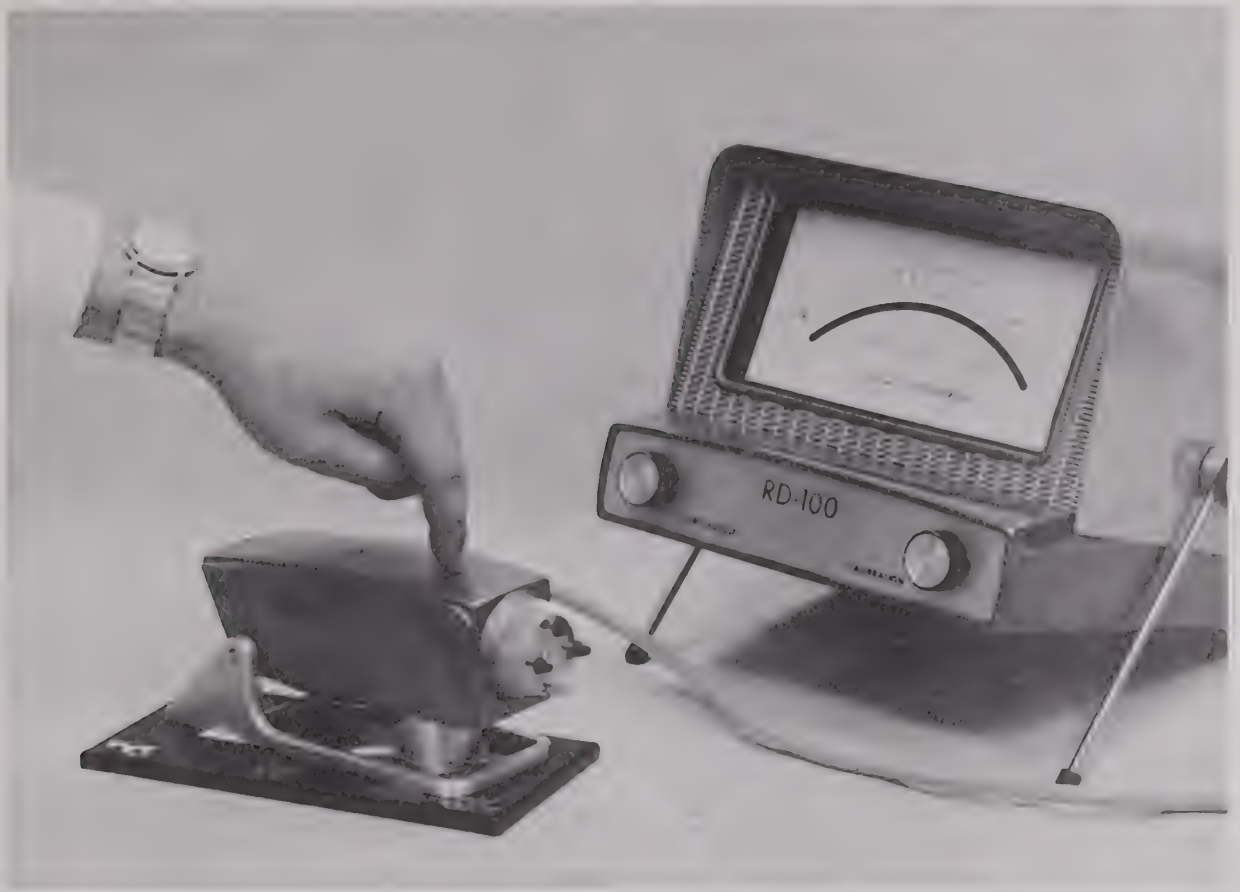


FIGURE 4

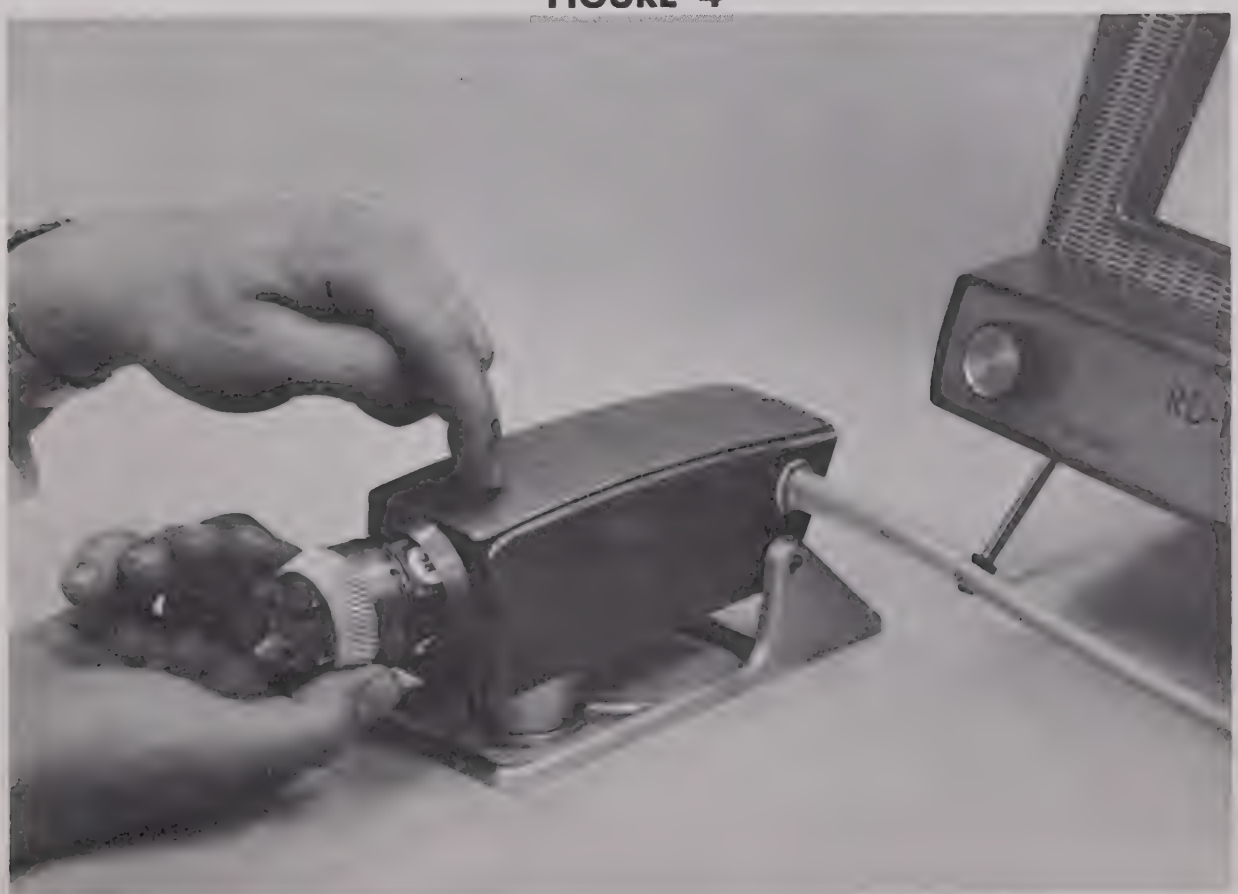
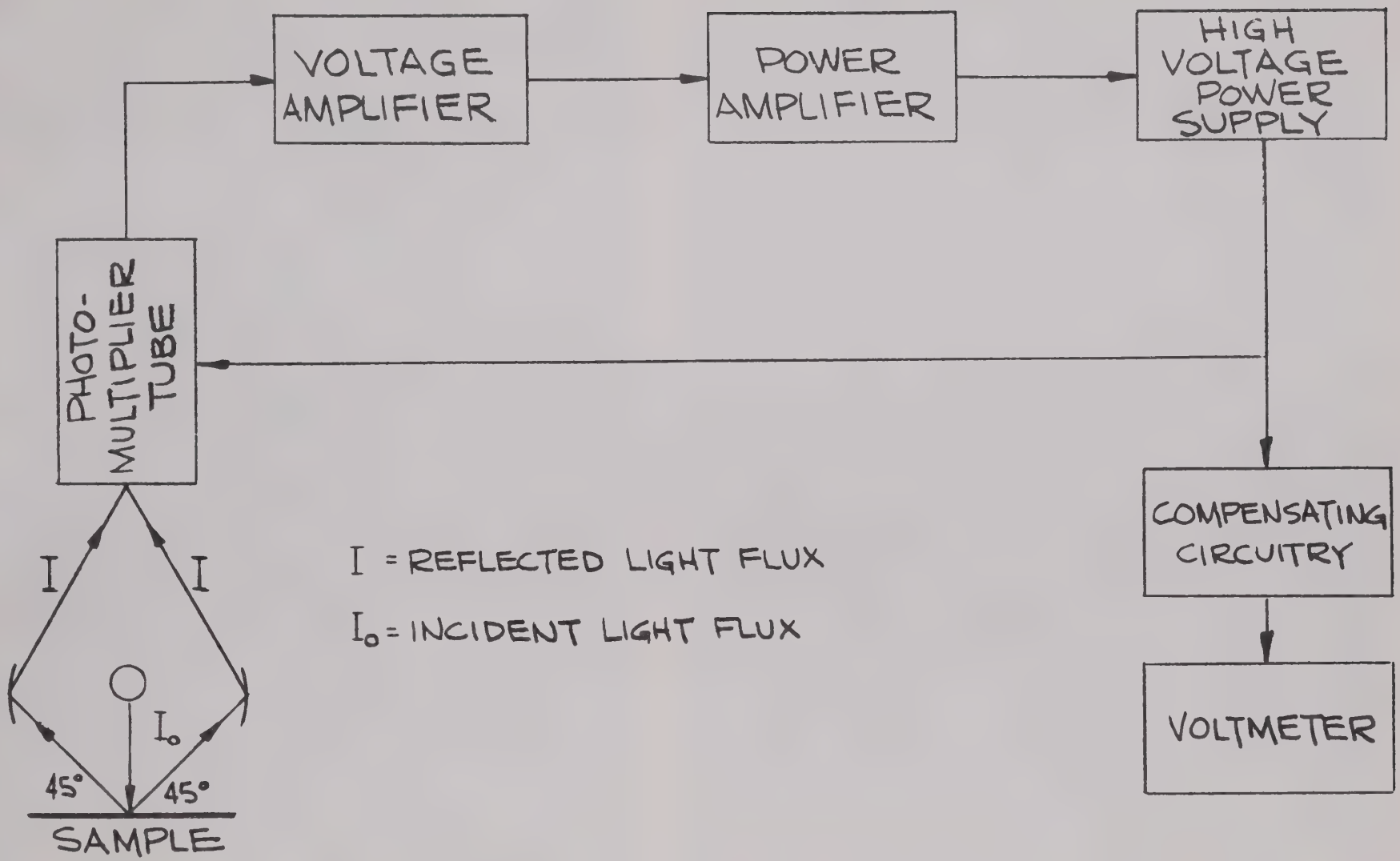
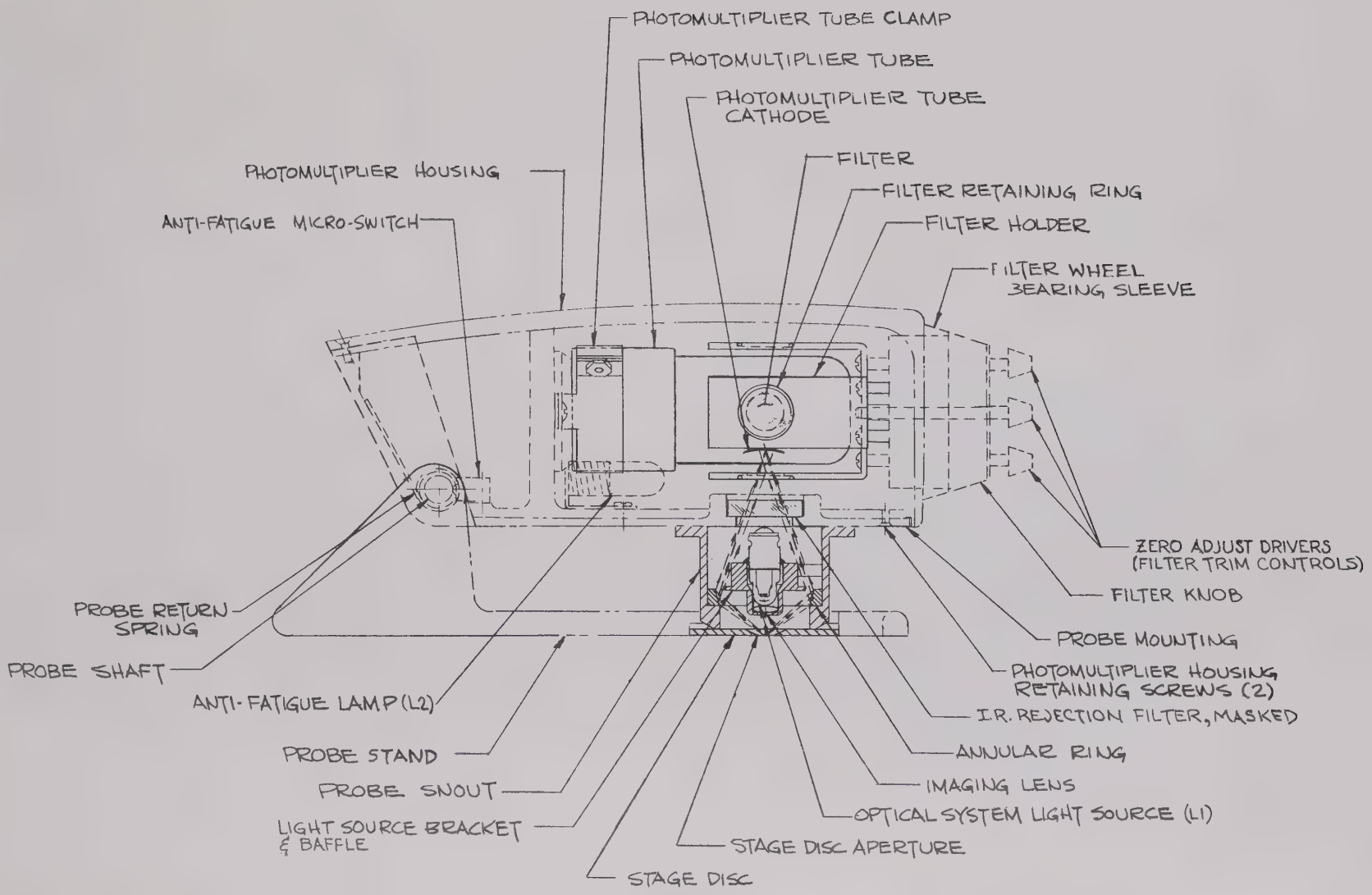


FIGURE 5



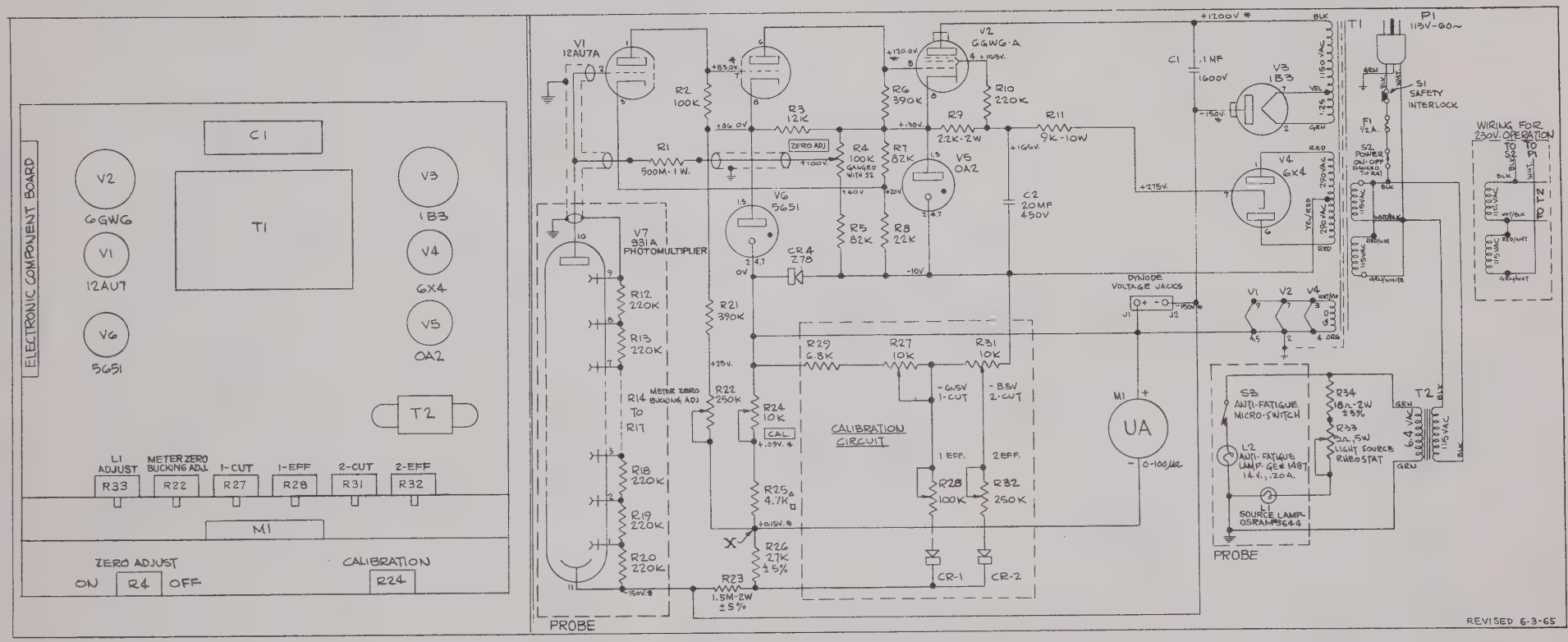
SYSTEM BLOCK DIAGRAM

FIGURE 6



OPTICAL SCHEMATIC - RD-100

FIGURE 7



NOTES-

1. ALL D.C. VOLTAGES MEASURED WITH A 20,000Ω/V. METER TO GROUND.
2. ALL A.C. VOLTAGES MEASURED WITH A V.T.V.M.
3. INPUT LINE VOLTAGE STABILIZED WITH 30 V.A. SOLA (CAT.#20-13-030) OPERATED AT 115V.
4. ALL VOLTAGES MEASURED WITH RD-100 CALIBRATED & PROBE IN UP POSITION.
   * TYPICAL SIGNAL VOLTAGES
5. THESE VALUES EFFECTIVE IN 52000 SERIES INSTRUMENTS

FIGURE 8

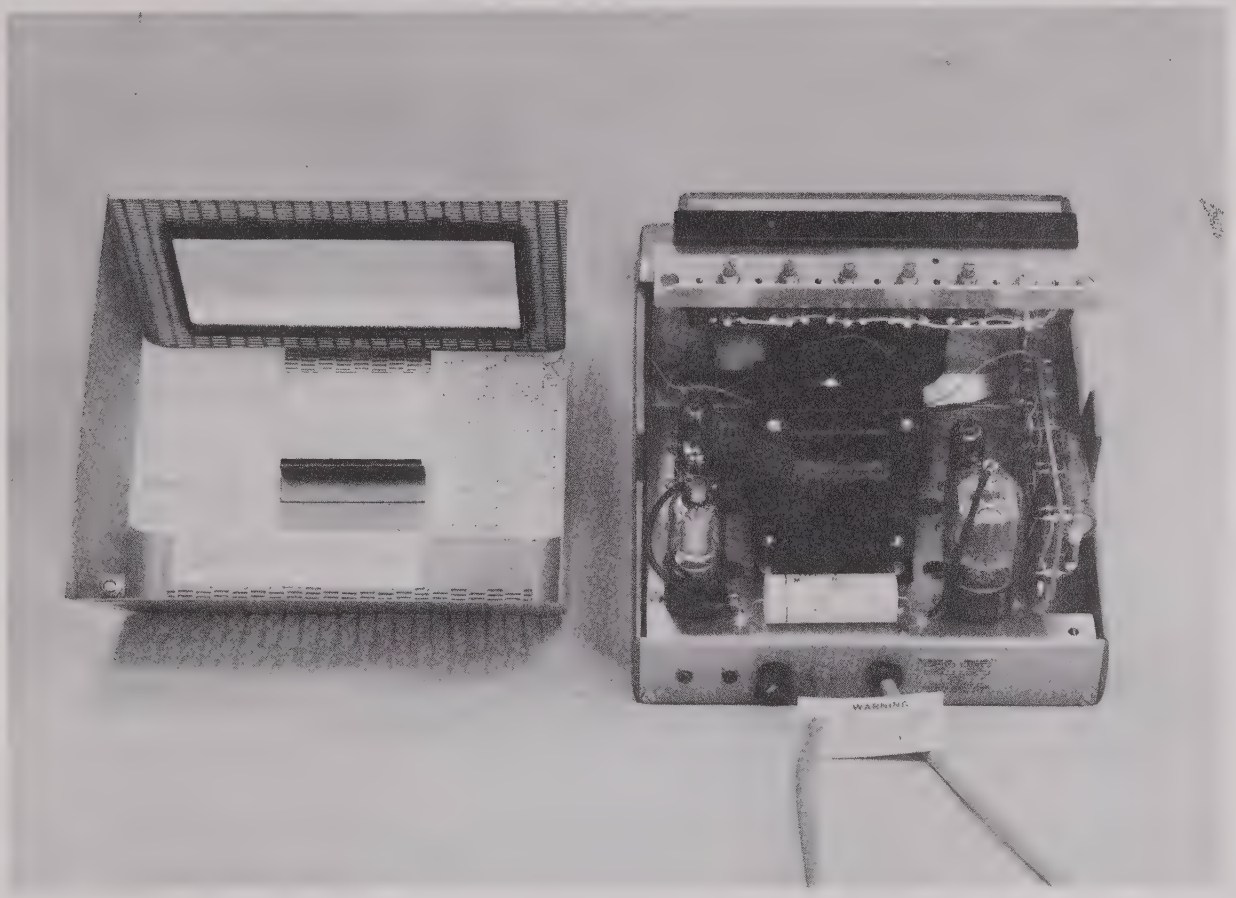
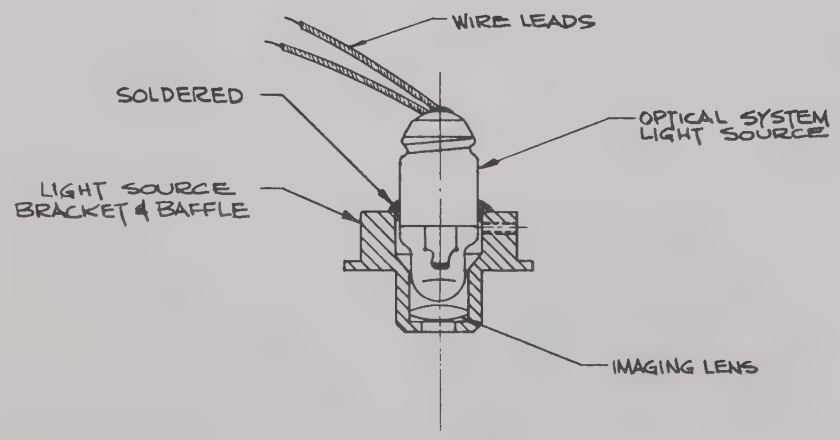


FIGURE 9

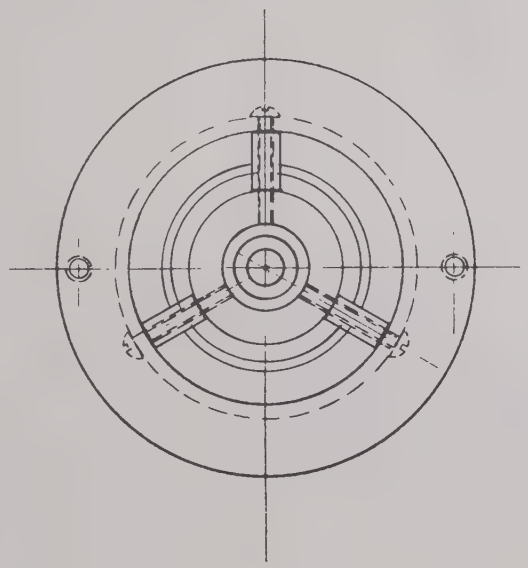


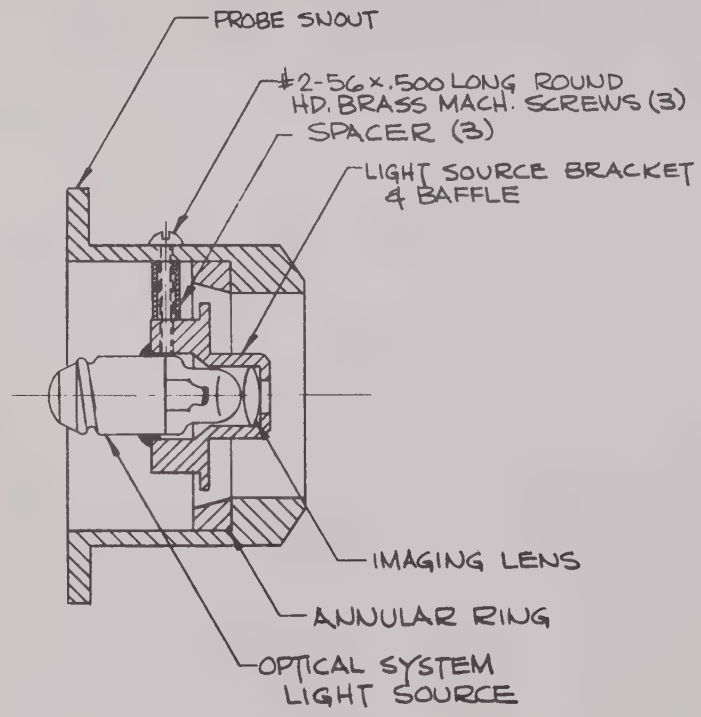
NOTE-
1. LIGHT SOURCE TO BE SOLDERED IN JIG TO ASSURE THAT IMAGE OF FILAMENT IS CENTERED & FOCUSED ON APERTURE OF STAGE DISC.

LIGHT SOURCE SUBASSEMBLY

FIGURE 10

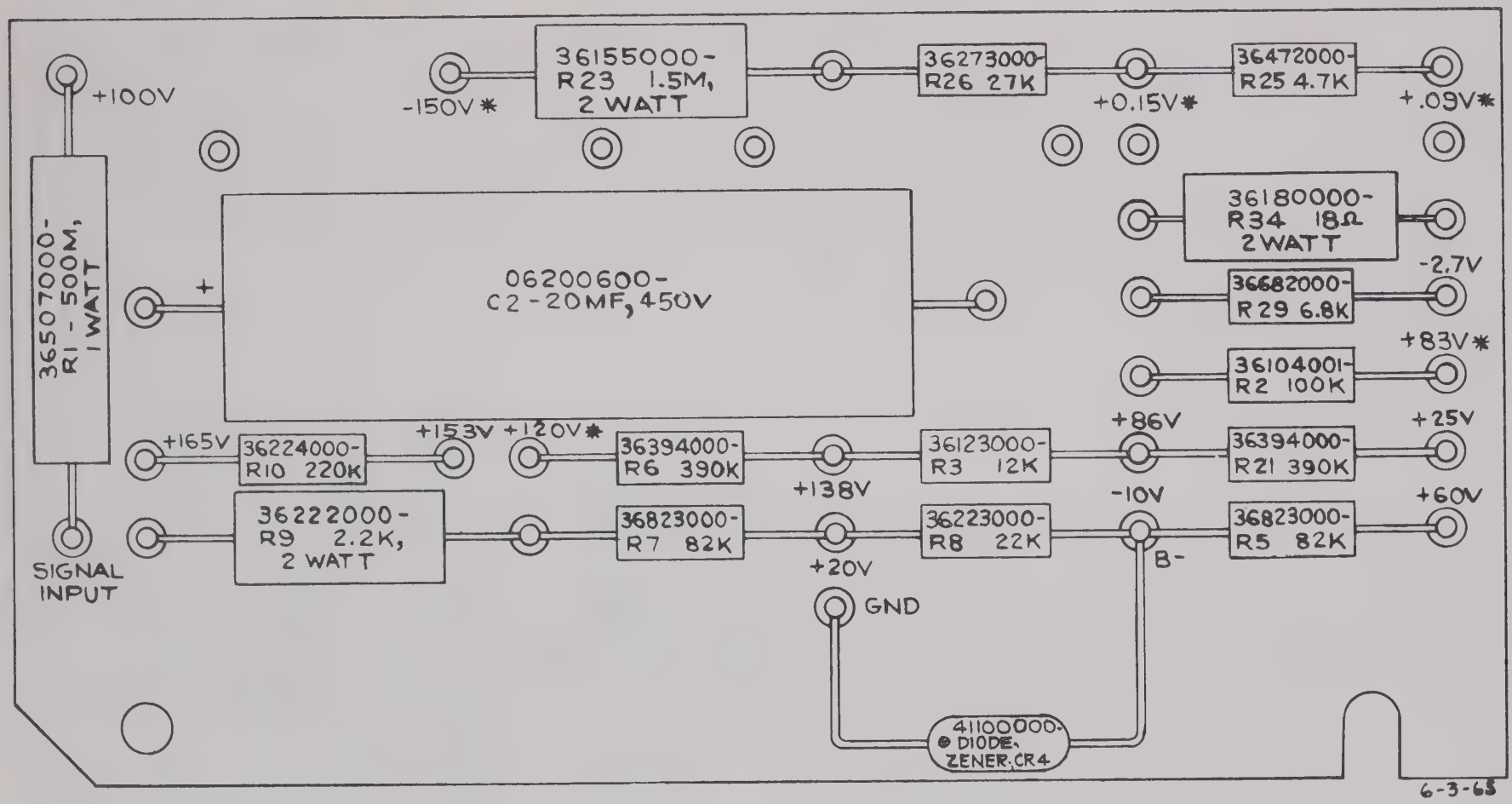
EC. NO.	APP'D	DATE





IMAGING AND COLLECTION OPTICS

FIGURE 11



NOTES —

1. ALL VOLTAGES TAKEN WITH 20,000 OHM / V. D. C. METER TO GROUND.
2. INPUT LINE VOLTAGE STABILIZED WITH 30VA SOLA (SER. #20-13-030).
3. ALL VOLTAGES MEASURED WITH RD-100 CALIBRATED & PROBE IN UP POSITION.

*TYPICAL SIGNAL VOLTAGES.

TERMINAL BOARD

EXHIBIT A

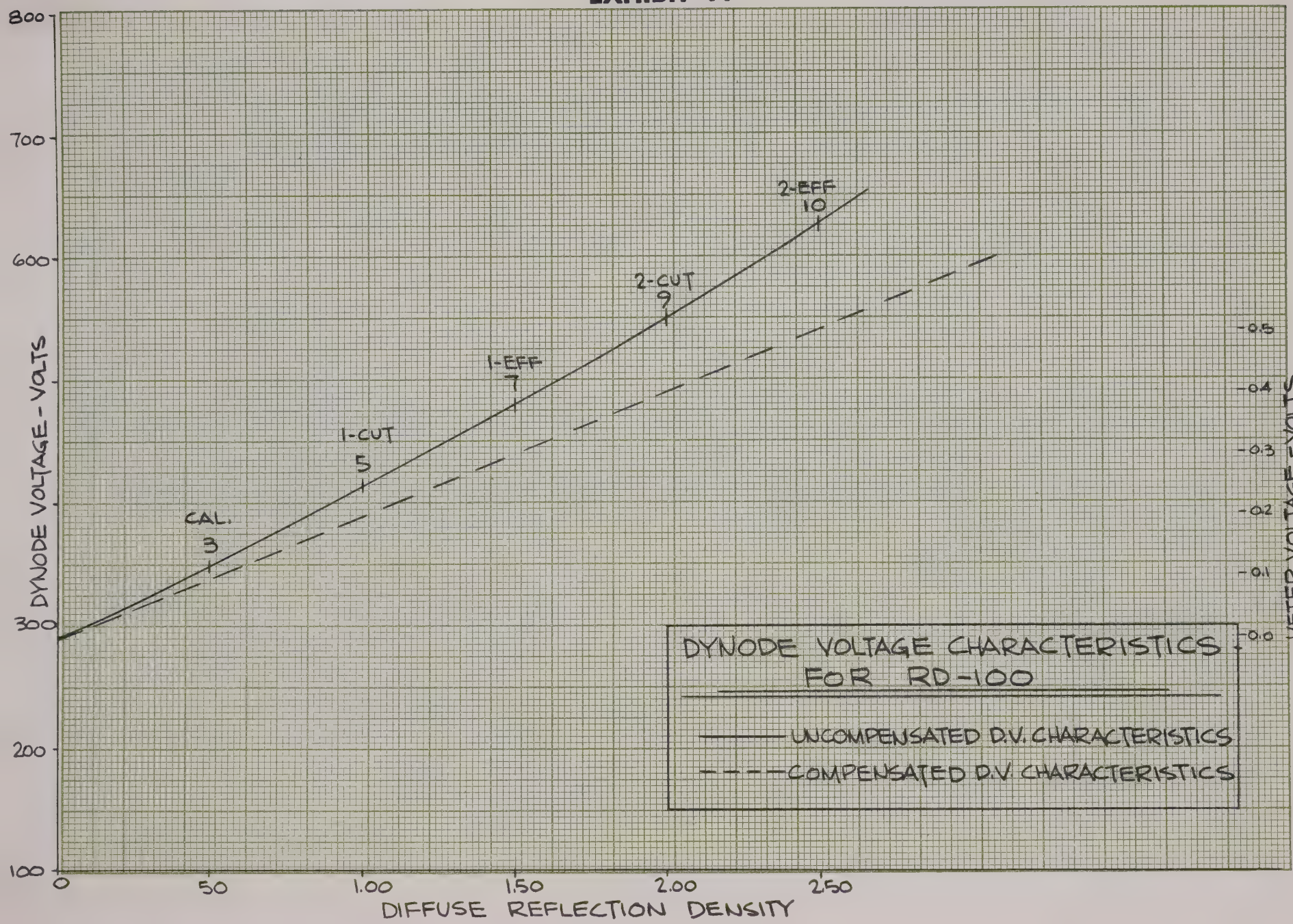

800
700
600
300
200
100
DYNODE VOLTAGE - VOLTS
0
50
1.00
1.50
2.00
2.50
DIFFUSE REFLECTION DENSITY
METER VOLTAGE - VOLTS
-0.5
-0.4
-0.3
-0.2
-0.1
-0.0
CAL.
3
1-CUT
5
1-EFF
7
2-CUT
9
2-EFF
10
DYNODE VOLTAGE CHARACTERISTICS
FOR RD-100
UNCOMPENSATED D.V. CHARACTERISTICS
COMPENSATED D.V. CHARACTERISTICS

EXHIBIT B

RD-100 TROUBLE SHOOTING GUIDE

Effect at Zero	Check	Fault
Meter Reads High Off Scale		12AU7 Open or out of Socket
Meter Reads High Off Scale	Read Approx. -30V. At 0A2 Pin-2, 4, and 7	IN1986 Open (CR-4)
Meter Reads High Off Scale	Meter Reads Low off Scale when 12AU7 Pin-2 Grounded.	931-A out of socket or cable conn. open
Meter Reads High Off Scale	Read Approx. + 70V at 6X4 Pin-7	6X4 open or out of socket
Meter Reads High Off Scale	Read 0.0V.A.C. at 6X4 Pin-1 or 6	Transformer (T1) open. 290VAC secondary
Meter Reads Approx. 2.0 Den.	Read approx. +150V, at 5651 Pin–1,5	5651 Open or Out of Socket
Meter Reads Approx. 2.0 Den.		500 MEG. Shorted (R_1) (Approx. 1.0 MEG.)
Meter Reads Approx. Zero	Read Approx. +300V, at 0A2 Pin-1 and 5	0A2 Open or Out of Socket
Meter Reads Approx. Zero, but out of Calib.	Read less than + 120V. at 0A2 Pin-1, 5	20 MF. (C2) shorted (Approx. 10K)
Meter Reads Below Zero		500 MEG (R1) Open
Meter Reads Below Zero	Read 0.0.V. at Dynode Volt Jacks	1B3 Open, out of socket, or open High volt. trans. winding (T1)
Meter Reads Below Zero, but Dynode Volt, too High	Read Approx. +108V, at 6GW6 Pin-8	6GW6 Open or out of Socket
Meter Reads Below Zero	Read 0.0V. at 0A2 Pin-2, 4, 7	IN1986 Shorted (CR-4) 0.0 OHMS

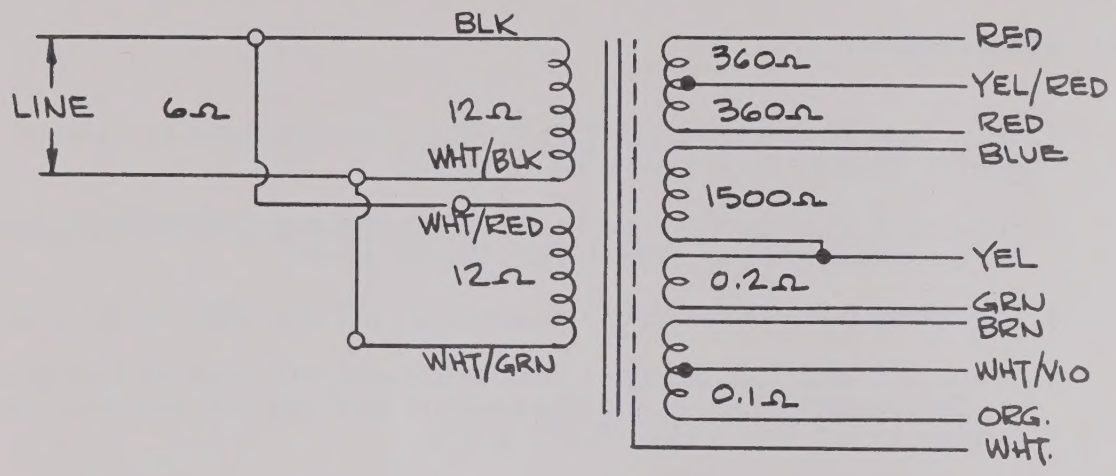
EXHIBIT C
D. C. VOLTAGE AND RESISTANCE MEASUREMENTS

Point of Measurement	D. C. Volts to Ground		Resistance to Ground (Ohms)
	Probe Up	Probe Down (2.00 Density)	
V1 - 12AU7			
Pin -1	82.8*	82.4*	190 K
2	Signal Input	Signal Input	>50 M.
3	20.5	20.5	23 K
6	122.5*	126.0*	510 K
7	82.8*	82.4*	190 K
8	86.0	86.0	71 K
Pin -4	153	153	300 K
5	122.5*	126.0*	510 K
8	138	138	63 K
Plate Cap	1020*	740*	>50 M.
V3 - 1B3			
Plate Cap	250*	-500*	930 K
V4 - 6X4			
Pin -7	275	275	73 K
V5 - OA2			
Pin -1, 5	138	138	63 K
2, 4, 7	-11	-11	350 Ohm
V6 - 5651			
Pin -1, 5	86.0	86.0	71 K
2, 4, 7	0.0	0.0	0.0
V7 - 931-A			
Pin -9	0.0	0.0	0.0
10	Signal Input	Signal Input	>50 M
11	-250*	-500*	930 K

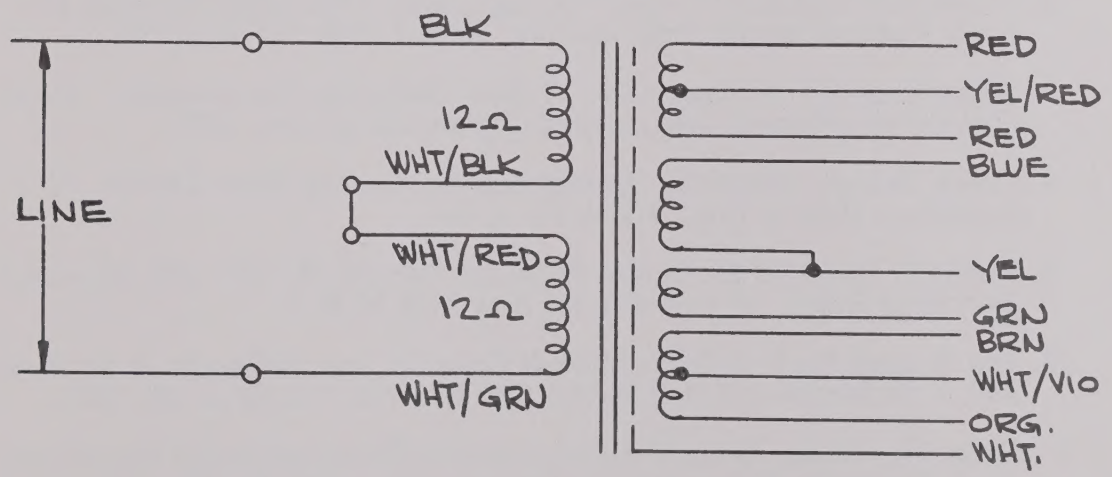
*Typical Signal Voltages

EXHIBIT D

POWER TRANSFORMER T-1 (115 VOLT OPERATION)



POWER TRANSFORMER T-1 (230 VOLT OPERATION)



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